Calloway & Schumacher

Life Tests of High Efficiency Incandescent Lamps

Electrical Engineering

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LIFE TESTS

OF

HIGH EFFICIENCY INCANDESCENT LAMPS

BY

RUSSELL THORNHILL CALLOWAY
LOUIS GUSTAV SCHUMACHER

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN

ELECTRICAL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF BACHELOR OF SCIENCE IN ELECTRICAL ENGINEERING

Morgan Brooks.

HEAD OF DEPARTMENT OF ELECTRICAL ENGINEERING

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Introduction.

The type of incandescent lamp in almost universal use at the present time is the carbon filament lamp. Recently, however, several new forms of incandescent lamps have been brought out. Among them are the metallized lamp, known as the G. E. M., and the tantalum filament lamp. Higher efficiencies are claimed for both these types of lamps. It has been proven by tests conducted in various parts of the country that the metallized filament lamp consumes only about .75 the energy of the carbon lamp of the same candle power, while the tantalum lamp consumes only about .6 the energy of the carbon lamp. Judging from these recent developments it looks as if a revolution in the incandescent lamp business was at hand. If these new types of lamps can show as long a life at higher efficiencies than the carbon lamp, they will undoubtedly supplant the latter. In view of this fact it was thought justifiable to conduct life tests upon a number of metallized, tantalum and carbon filament lamps, so as to compare the performance of the two former to the latter as regards efficiency and length of life. The lamps were burned upon both direct and alternating current.

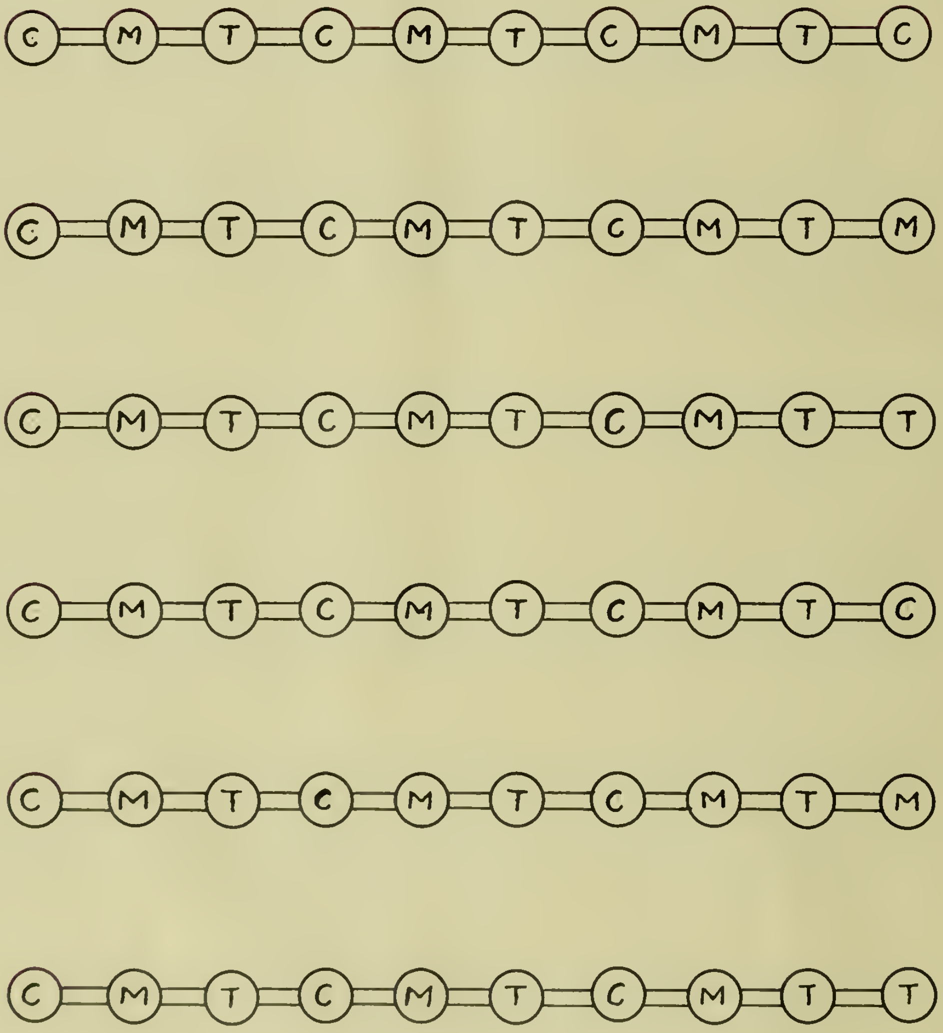
The lamps used in these tests were selected from an assortment of 100 carbon, 100 metallized, and 100 tantalum lamps which came direct from the manufacturers. From this number 20 carbon, 20 metallized and 20 tantalum lamps were selected after careful preliminary testing.

Preliminary Tests.

The lamps were first placed upon a low voltage, approximately 60 volts. In this manner any weak spots in the filaments could be detected. Crookedness or other irregularities were also noted. Then the lamps were tested for grounds in the base, and were also subjected to the usual vacuum test. After these tests the candle power of each individual lamp was measured. This was done upon the three meter photometer bar by comparison with a standard incandescent lamp which had been calibrated in the Electrical Testing Laboratories at New York. Only the mean horizontal candle power was measured. The lamp tested was placed in an upright position at one end of the photometer bar, and its full normal voltage, 110 volts, impressed upon it. It was then rotated at 180 revolutions per minute, the power for this being supplied by a 1/20 horse power induction motor. The standard lamp was placed in an upright position at the other end of the photometer bar. The candle power of the lamp tested was calculated from the photometer screen reading. The current consumption of each lamp was measured at the same time, and then its efficiency in watts per candle power was calculated.

From the results of these preliminary tests the lamps for the life tests were selected. All lamps whose filaments exhibited any weak spots on low voltage, or were unusually crooked, and also those which showed a poor vacuum, were discarded. In selecting lamps according to their candle power, those lamps which were nearest the rated candle power were chosen. Thus the

Diagram showing arrangement of Lamps



Ⓒ Carbon
Ⓜ Metallized
Ⓣ Tantalum

tantalum lamps were rated at 22 candle power, and all those which showed 22 candle power were chosen in preference to those which may have given off 23 or 24 candle power. The same rule applied in selecting lamps according to their current rating. All of the lamps had been numbered previous to any preliminary testing, and in this manner the different lamps were distinguished from each other.

Life Tests.

After the final selection had been made, the lamps were placed upon the newly constructed lamp banks in the attic of the electrical building. Thirty lamps, 10 of each kind, were placed upon direct current and the same number upon alternating current. The lamps were arranged in the bank as shown by the diagram. This arrangement gave equal heating effect, and equal voltage drop to the different kinds of lamps. The lamps were placed in a vertical position, tip downward. Each lamp was kept in the same socket throughout the test. The current was turned on at 10:00 P. M., March 7, 1907, and the test continued for 700 hours. The candle power and current consumption of each lamp were measured after approximately the following periods: 10, 20, 30, 40, 60, 100, 200, 300, 400, 500, 600 and 700 hours. In order to insure a very nearly constant voltage, the dirrect current was supplied by the storage batteries. The batteries were "floated," that is, as much current was sent into them continuously throughout the test as was taken out by the lamp. In this manner a very nearly constant voltage was obtained. To get a constant voltage on the alternating

current, the 45 kilowatt machine in the University power plant was used exclusively for this test. The field circuit of this machine was brought up to the attic and a 24 ohm rheostat inserted at this point. By this arrangement the voltage of the machine could be controlled from the attic. The voltage remained fairly constant but at times it varied considerably. There was also much vibration in the bank, which, no doubt, had much to do with shortening the life of the metallized filament lamps.

Results of Life Tests.

The results obtained from this test are shown by the observed and calculated data. In plotting curves from the data obtained, attempt was made to average up the performance of the different lamps. Accordingly 18 lamps, 6 of each kind, three of which had been burned upon direct and three on alternating current, were chosen. The lamp which showed the best, the one which gave an average, and the one which showed the poorest were taken and from the data taken for these lamps, a fair average performance could be calculated. Curves were plotted for the 18 lamps between candle power and time and time and watts per candle power. The curves between candle power and time in hours for the carbon lamps rose gradually during the first 40 or 50 hours of the test and then fell off gradually until the 700 hour mark was reached. The curves plotted for the metallized filament lamps showed them to be in a rather unstable condition as to candle power during the first 50 hours of the test. The figures obtained at these points are probably due to improper calibration of the test lamps, rather than

the variation in candle power of the lamps themselves.

After this they fell off in candle power but not with nearly so much rapidity as the carbon lamps. The metallized filament lamps on direct current fell from about 20 candle power at the start to about 16 candle power at the end of 700 hours. On alternating current the same lamps fell from 20 to about 15 candle power in 700 hours. The carbon lamps, however, fell from about 25 to 17.5 candle power on direct current and from 25 to about 13 candle power on alternating current. The curves plotted for the tantalum lamps rise very abruptly during the first fifty hours. Those burning on direct current showed a very rapid falling off in candle power during the second hundred hours, after which they diminished in candle power more uniformly. The tantalum lamps burned upon alternating current showed a very rapid rise in candle power during the first fifty hours and fell off very rapidly during the next two hundred. The tantalum lamps on direct current fell from 20 to about 17.5 candle power during the test while the ones burned upon alternating current dropped from 19.7 candle power at the start to 15 candle power at the end. It will be seen that the candle power of all lamps was cut down faster on alternating current than upon direct current. This was no doubt due to the poorer voltage regulation on the alternating current.

As regards life only, the carbon lamps showed superiority to either of the other new types. Of the 20 lamps started only one had burned out at the end of 700 hours, and it burned for 588 hours. The metallized filament lamps showed very poorly. Seven of them had burned out at the end of 700 hours and six of

these were upon alternating current. This rapid burning out of lamps was no doubt due to the fact that the metallized lamps tested were in small units, 25 candle power. The filaments of these lamps had to be made so small that they burned out easily. The proper size unit for the metallized lamp seems to be about 50 candle power. In this size the filament is of such cross section that it is not easily weakened by jarring or rough handling. The tantalum lamps had a fairly long length of life. Four burned out on alternating and two on direct current. According to all literature which had been previously published concerning the life of tantalum lamps, the results obtained were contrary to what had been expected. It had been stated many times in current periodicals that the average life of the tantalum lamp on alternating current was only about one-half that of the carbon. Taking the average life of the carbon lamp on alternating current to be 800 hours, all of the tantalum lamps on alternating current should have burned out at about 400 hours. At this time, however, only two had burned out, and at the end of 700 hours only four of the lamps had burned out.

However, the average consumer of electric light is more interested in the cost per candle power hour of light than he is in the relative life of the different kinds of lamps. With this fact in view the average candle power given out during the test by the different lamps on different currents was calculated for the three representative lamps. The average watts per candle power were also calculated. Taking the cost of electric energy at 15 cents a kilowatt hour and the length of the test being 700 hours

the cost per candle power hour for the various kinds of lamps could be found. These results were calculated and are given in the table below.

Lamp No.	Ave. Candle Power	Ave. Watts per C.P.	K.W.H. Consumed in 700 hrs.	Cost of Energy at 15¢ a K. W. H.	Cost per C.P.H.	Kind of Lamp and Current
258	21.4	3.48				Carbon
237	22.2	3.40				on
249	21.0	3.50				D. C.
Ave.	21.5	3.46	52.3	$7.86	$.000521	
274	19.1	3.92				Carbon
235	19.3	3.84				on
270	18.5	3.92				A. C.
	19.0	3.89	51.9	$7.78	$.000585	
13	18.4	2.91				G.E.M.
32	17.6	2.88				on
24	18.6	2.87				D. C.
	18.2	2.89	36.85	$5.52	$.000433	
70	16.8	2.84				G.E.M.
37	18.4	2.90				on
45	19.8	3.04				A. C.
	18.3	2.93	37.6	$5.65	$.000439	
141	20.5	2.00				Tantalum
136	21.5	1.97				on
147	20.0	2.07				D. C.
	20.7	2.01	29.35	$4.40	$.000303	

Lamp No.	Ave. Candle Power	Ave. Watts per C.P.	K.W.H. Consumed in 700 hrs.	Cost of Energy at 15¢ a K. W. H.	Cost per C.P.H.	Kind of Lamp and Current
152	20.2	1.98				Tantalum
156	20.1	1.92				on
188	20.3	2.13				A. C.
	20.2	2.01	28.4	$4.26	$.000300	

The figures in this table show the saving in electric light bills effected by the use of the tantalum or metallized filament lamps. These new types of lamps, however, cost more than the carbon lamp. The cost per hundred is about as follows:

Carbon:	25 candle power	$17 per hundred
Metallized:	25 " "	$25 " "
Tantalum:	22 " "	$51 " "

The saving to the consumer by the use of tantalum or metallized lamps over carbon can be illustrated by a specific case. A user of electric light in a city of 10,000 people has a building which requires 100 lamps to light. In as much as the alternating current system of distribution is usually used in a city of this size, only the results obtained from the use of alternating current in the tests will be used. The average useful life of both carbon and tantalum lamps will be considered to be 700 hours, while the metallized filament lamp will be considered to have an average useful life of only 350 hours. This will necessitate one complete renewal of the metallized filament lamps. Take the case where the consumer invests in carbon lamps, with which to light his building.

100 lamps cost ---------------- $17

Each lamp consumes $7.78 worth of energy in 700 hours

100 X $7.78 = $778

Total Cost = $778 + $17 = $795.

In case the consumer buys 100 tantalum lamps for his building

100 lamps cost ---------------- $51

Each lamp consumes $4.26 worth of energy in 700 hours

100 X $4.26 = $426

Total Cost = $426 + $51 = $477.

Saving by the use of tantalum lamps

$795 - $477 = $318.

According to the results obtained from this test, the average useful life of the tantalum lamp was somewhat less than 700 hours, but even allowing for renewals of one or two lamps the saving over the carbon lamps would be some where near $300. In a city where direct current was used for lighting purposes, the saving in the use of tantalum lamps would be even greater, for the tantalum has about the same life on direct current as the carbon lamp.

Now consider the case where metallized filament lamps are used and, owing to the poorly regulated alternating current circuit, assume that two sets of lamps will have to be used in 700 hours' time.

200 lamps cost --------------- $50

Each lamp consumed $5.65 worth of energy in 700 hours

100 X $5.65 = $565

Total cost $565 + $50 = $615

Saving over carbon lamps by use of metallized

$795 - $615 = $180.

Conclusions.

There are several conclusions which may be drawn from this test. The first is that the tantalum and metallized filament lamps as regards current consumption are much more efficient than the carbon. Second, the metallized filament lamp should not be made in sizes smaller than 40 or 50 candle power, unless they are to be used upon well regulated circuits where there is little vibration and no rough handling. When the lamp is made in 25 candle power units, the filament is of so small a cross-section that it is easily ruptured by rough handling or excessive vibration.

Probably the most important conclusion arrived at is the fact that for commercial and domestic uses the tantalum lamp is vastly superior to the old carbon lamp. True it is that the carbon lamps may have had a slightly longer life in this test than the tantalum, but the fact that the carbon lamp has been on the market for about 25 years while the tantalum lamp has been brought out just recently leads to the conclusion that there is a future for the new type. During the last quarter century, manufacturers have by experience, research and investigation learned to make the carbon lamp until to-day it is as near perfection as the carbon lamp can be. As soon as more experience is obtained in the manufacture of the tantalum and metallized filament lamps, the makers will no doubt be able to produce a lamp which will be as durable as the carbon lamp, will have just as long a

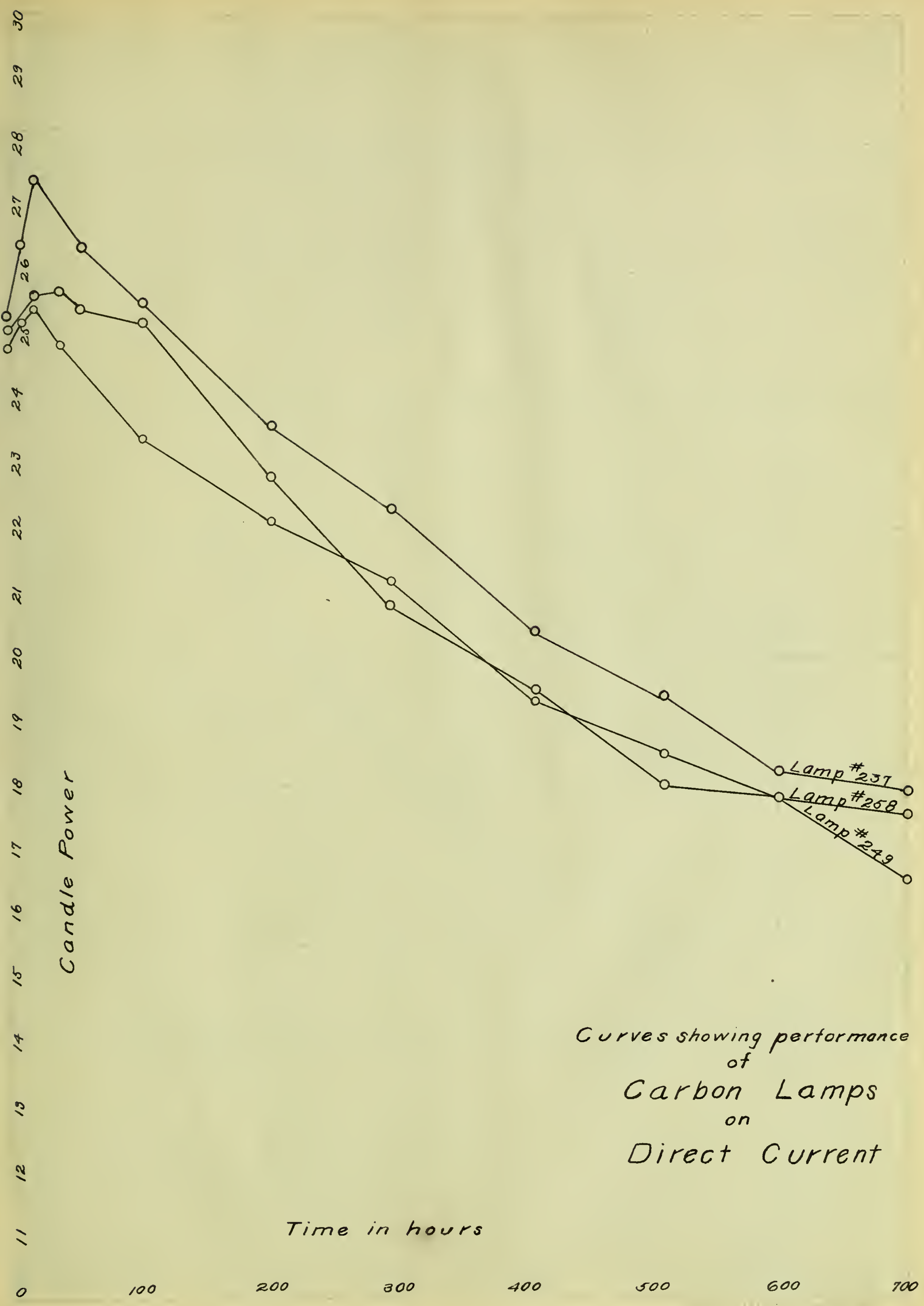
life at a much higher efficiency. It may not be either of these two new forms. It may be the new tungsten or helium lamps, but all signs seem to point to a radical change in interior lighting during the next few years. There is a saying that an article is all right until some one has produced something better. No sensible man would to-day think of putting in a horse car railway to compete with an electric trolley. If the new forms of incandescent lamps can be made so as to have as long a life as the carbon lamp at a much higher efficiency, it would be folly to continue to use the old lamps.

The new forms of lamps will bring the electric light into much greater use. The poorer class of people will be able to light their homes with it while the richer people will be able to give their homes a more decorative appearance by concealed lighting, frosted globes, etc.

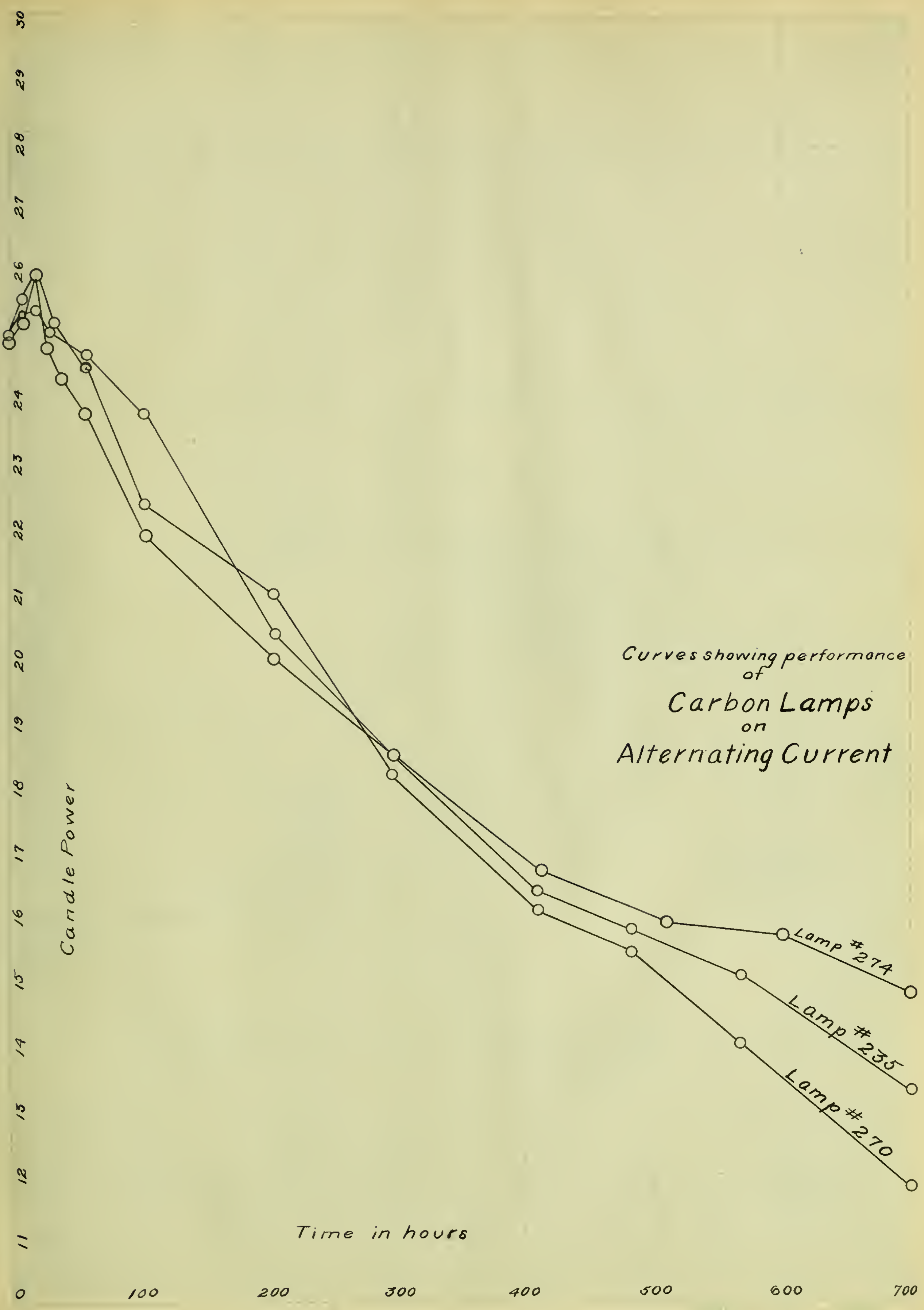
Acknowledgments.

The writers of this thesis take this means of thanking Mr. T. H. Amrine of the Engineering Experiment Station for his help and untiring interest in the work.

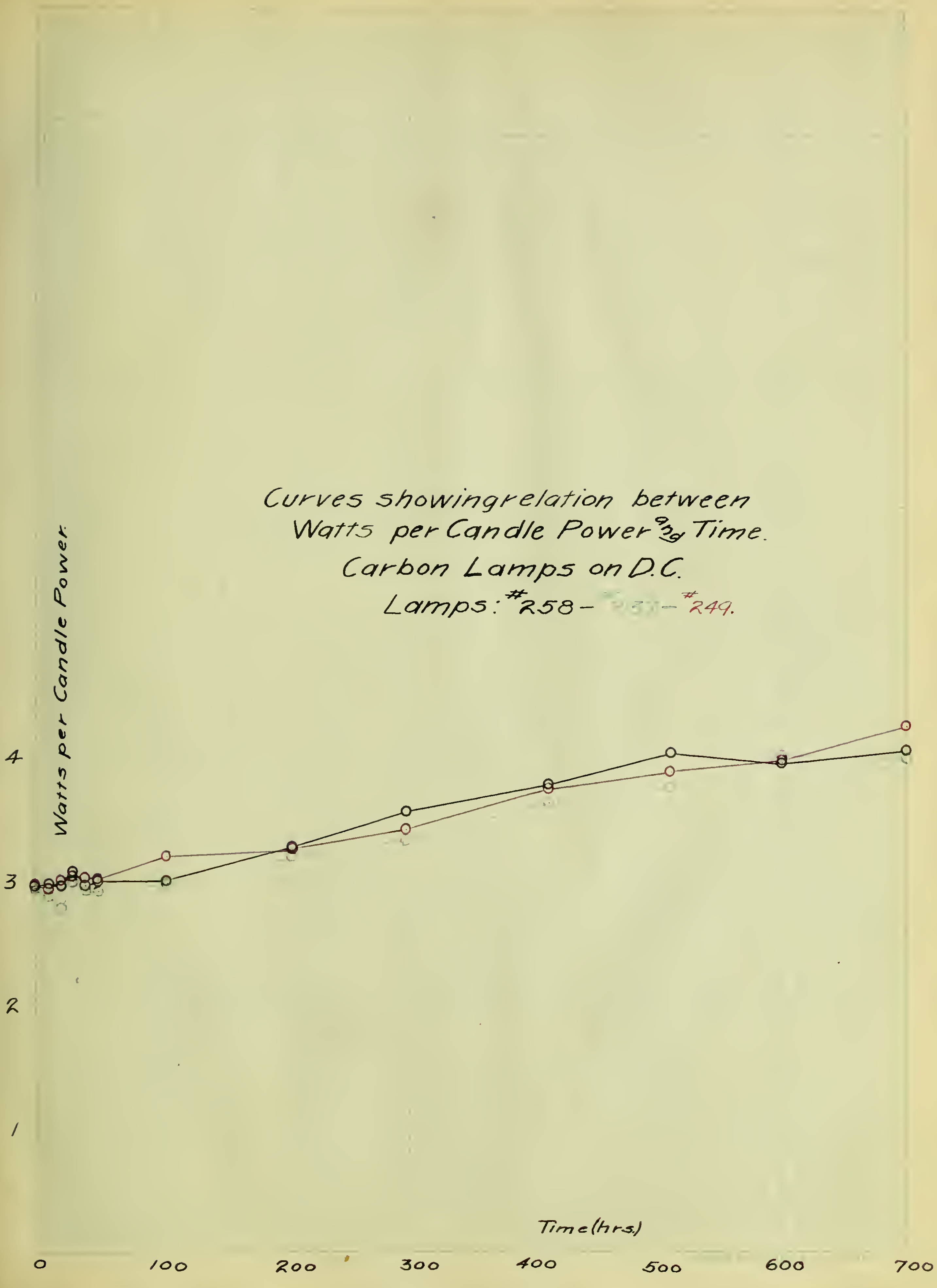
Thanks are also due Mr. J. M. Bryant of the Electrical Engineering Department for his many valuable suggestions.



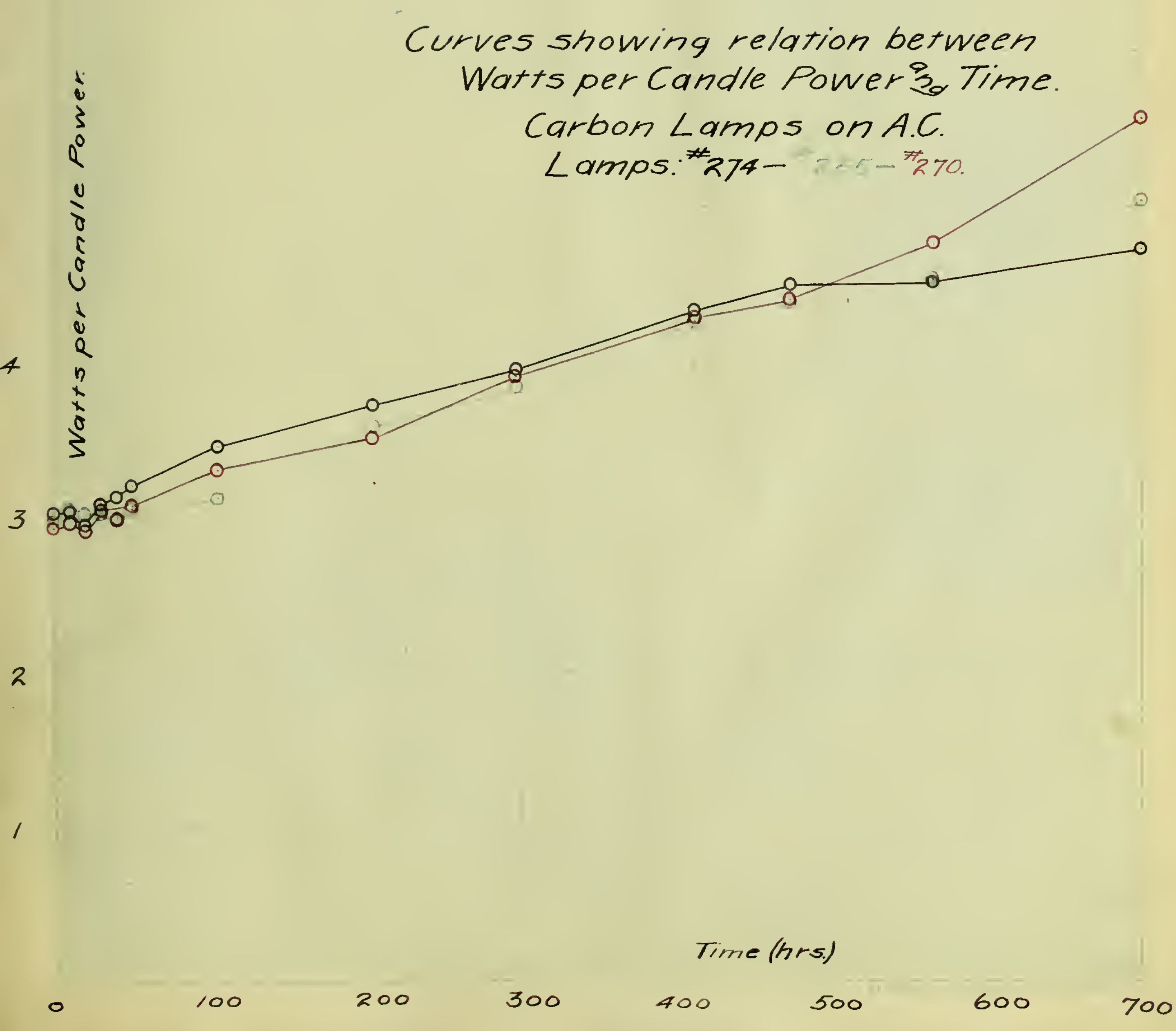
Curves showing performance of Carbon Lamps on Direct Current

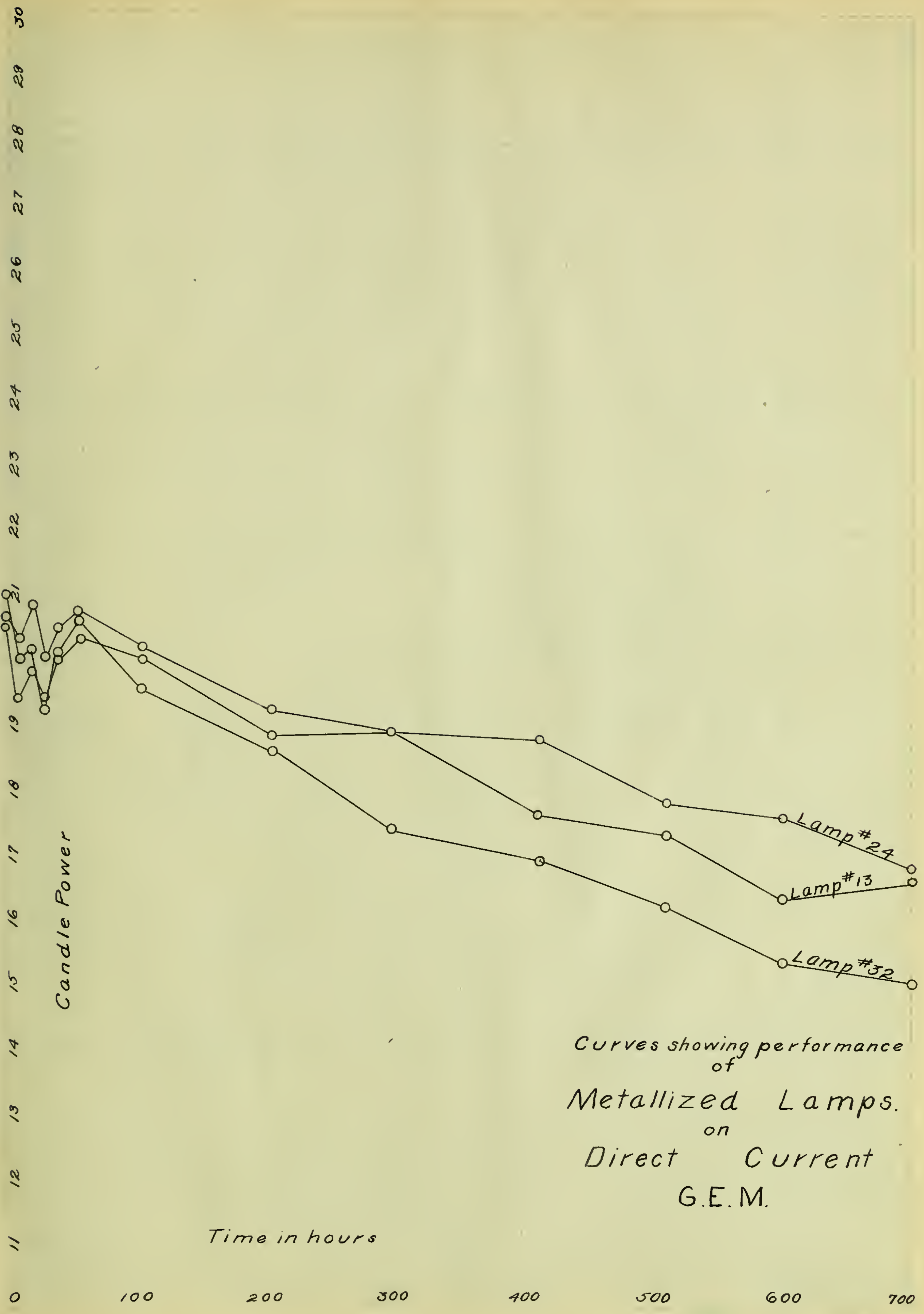


Curves showing performance of Carbon Lamps on Alternating Current

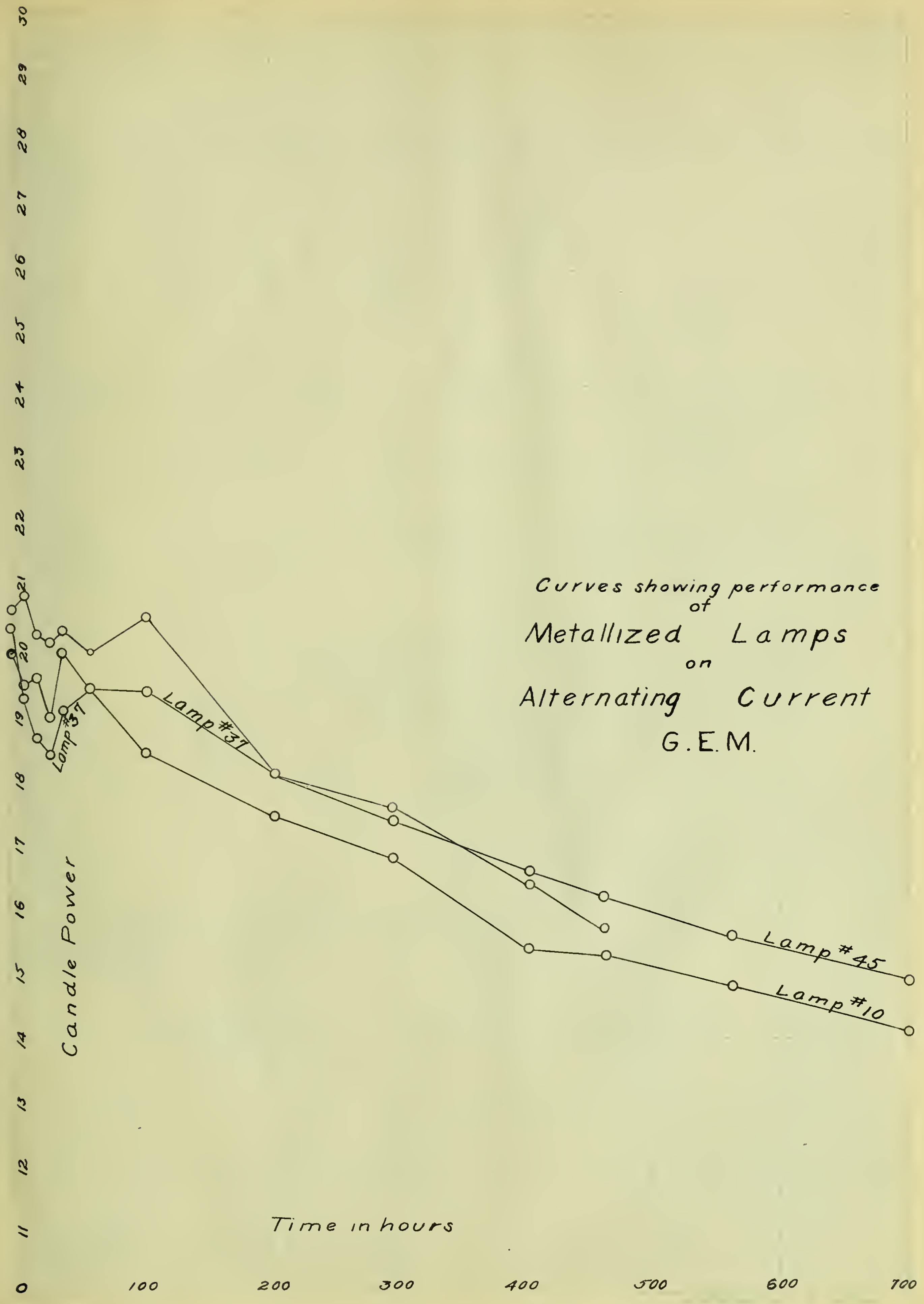


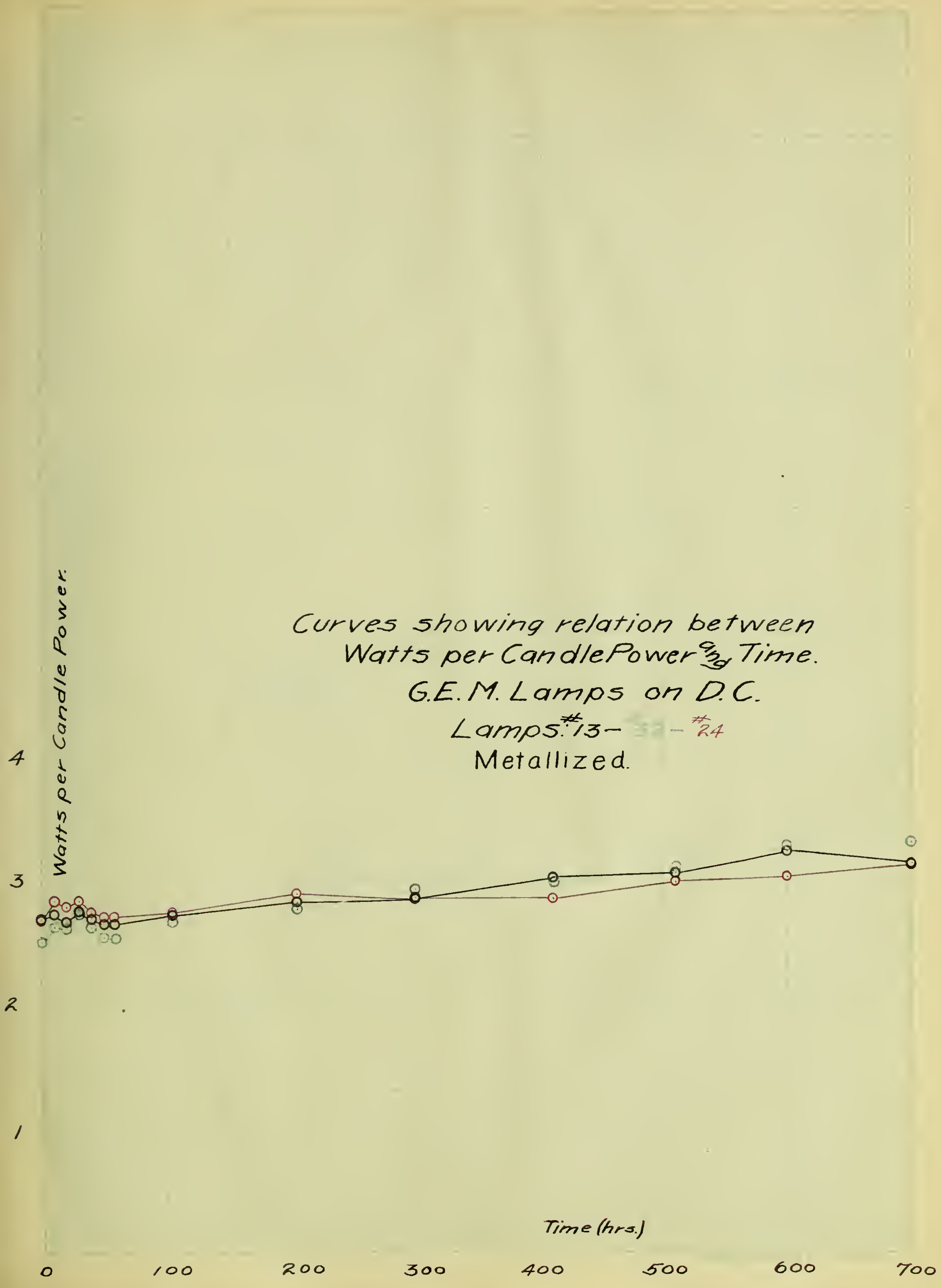
Curves showing relation between
Watts per Candle Power and Time.
Carbon Lamps on D.C.
Lamps: #258 - #237 - #249.

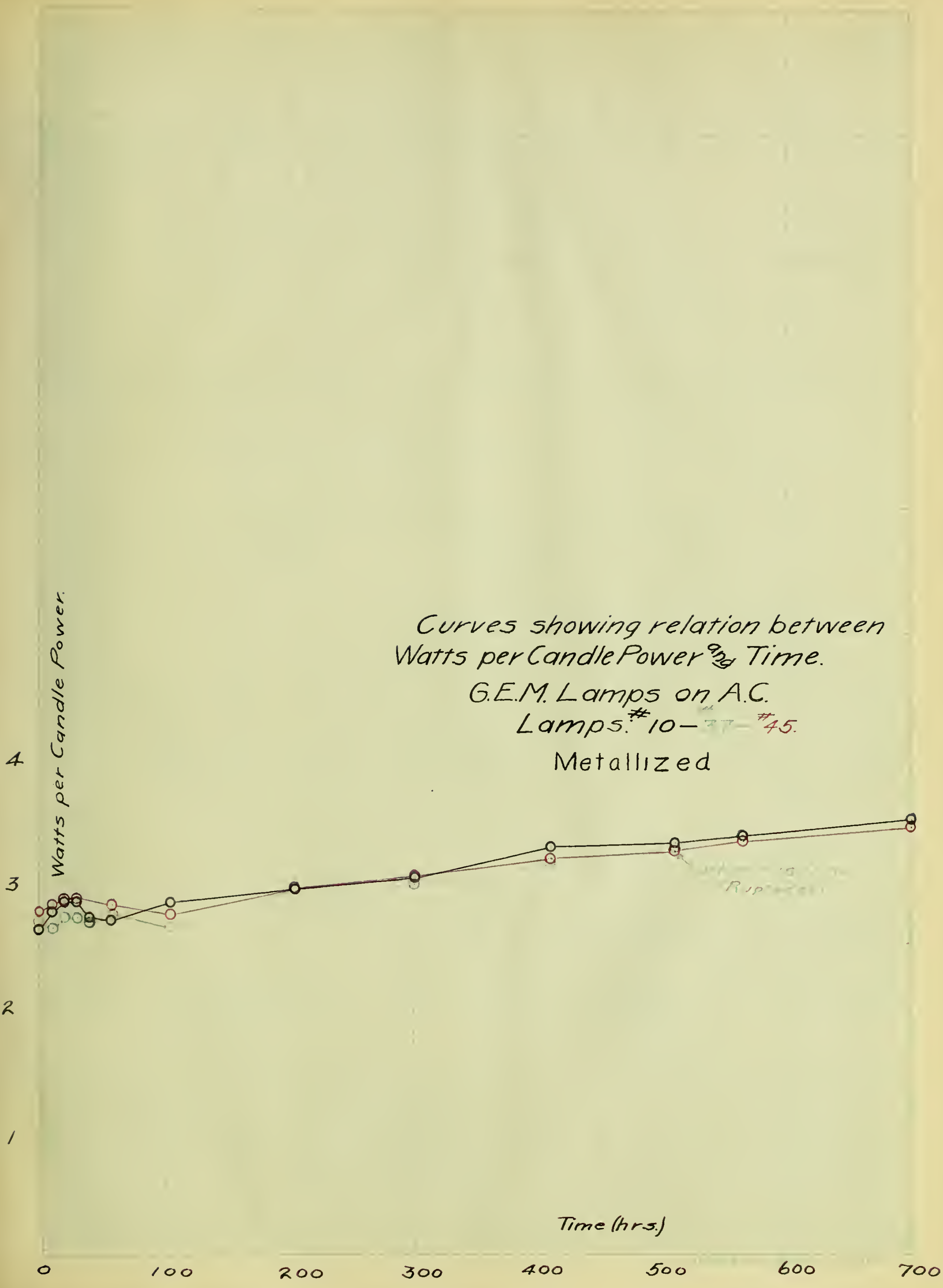

Curves showing relation between
Watts per Candle Power and Time.
Carbon Lamps on A.C.
Lamps: #274 — [illegible] — #270.



Curves showing performance
of
Metallized Lamps.
on
Direct Current
G.E.M.

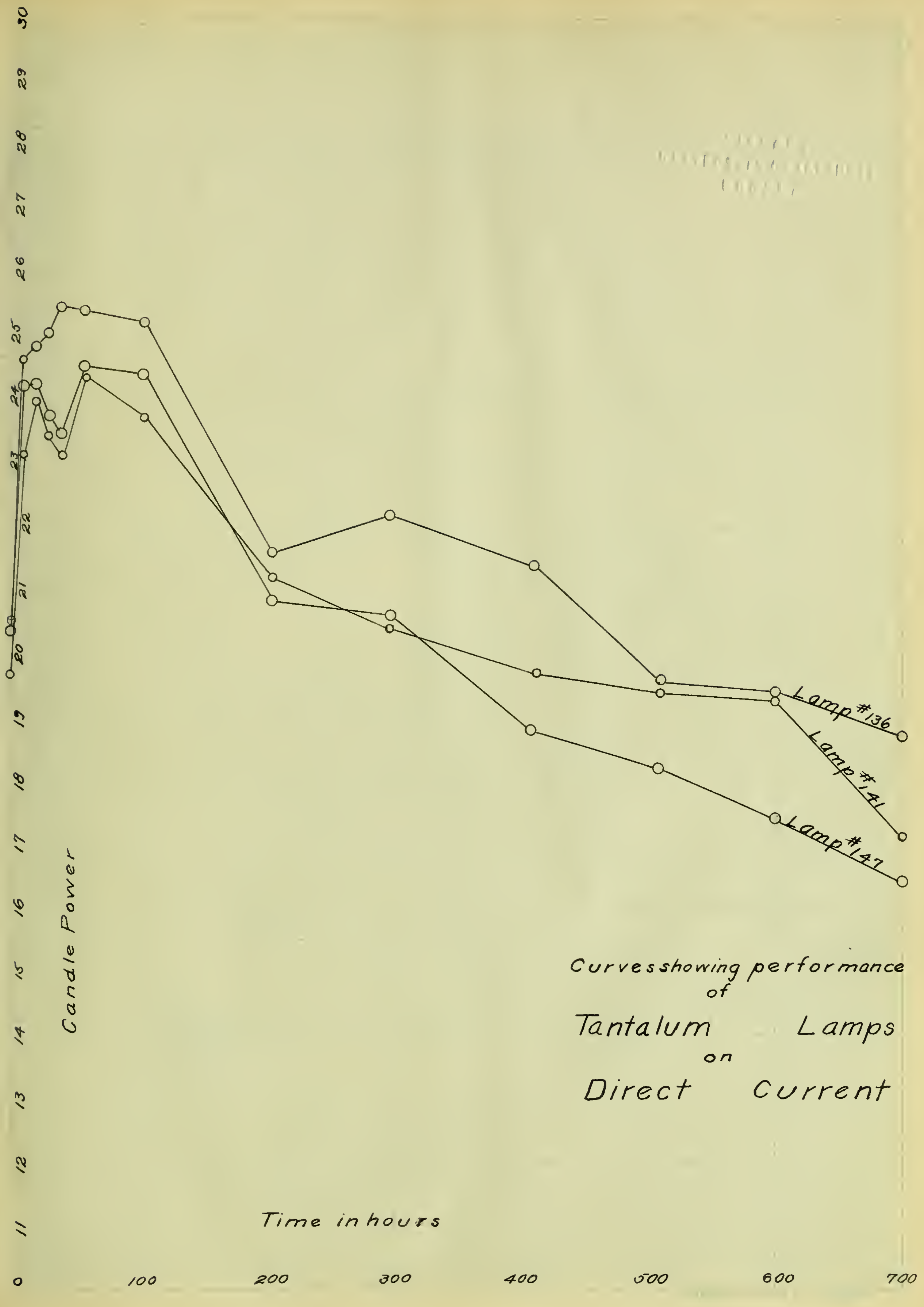

Curves showing performance of Metallized Lamps on Alternating Current G.E.M.


Curves showing relation between
Watts per Candle Power and Time.
G.E.M. Lamps on D.C.
Lamps: #13 - [illegible] - #24
Metallized.

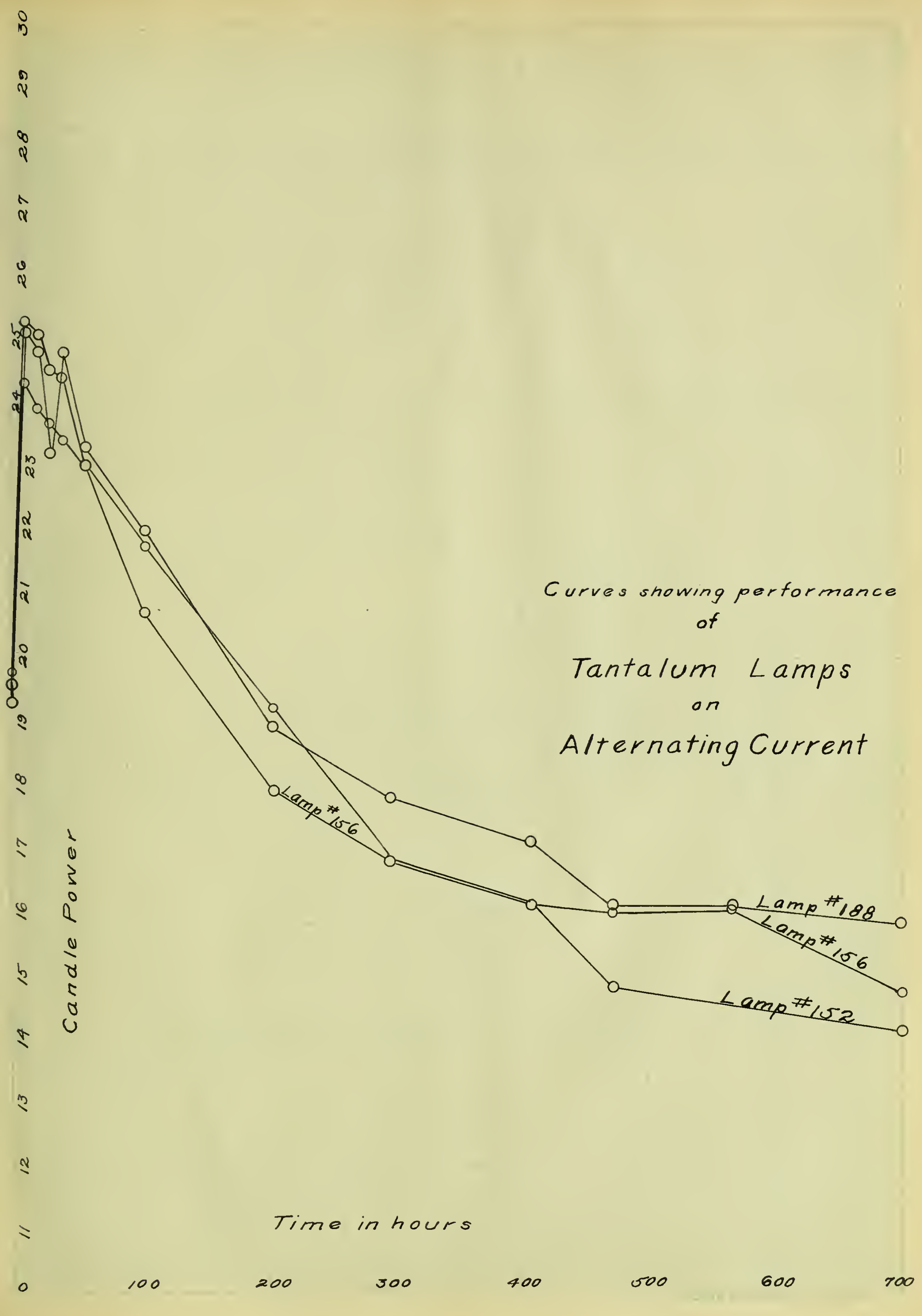


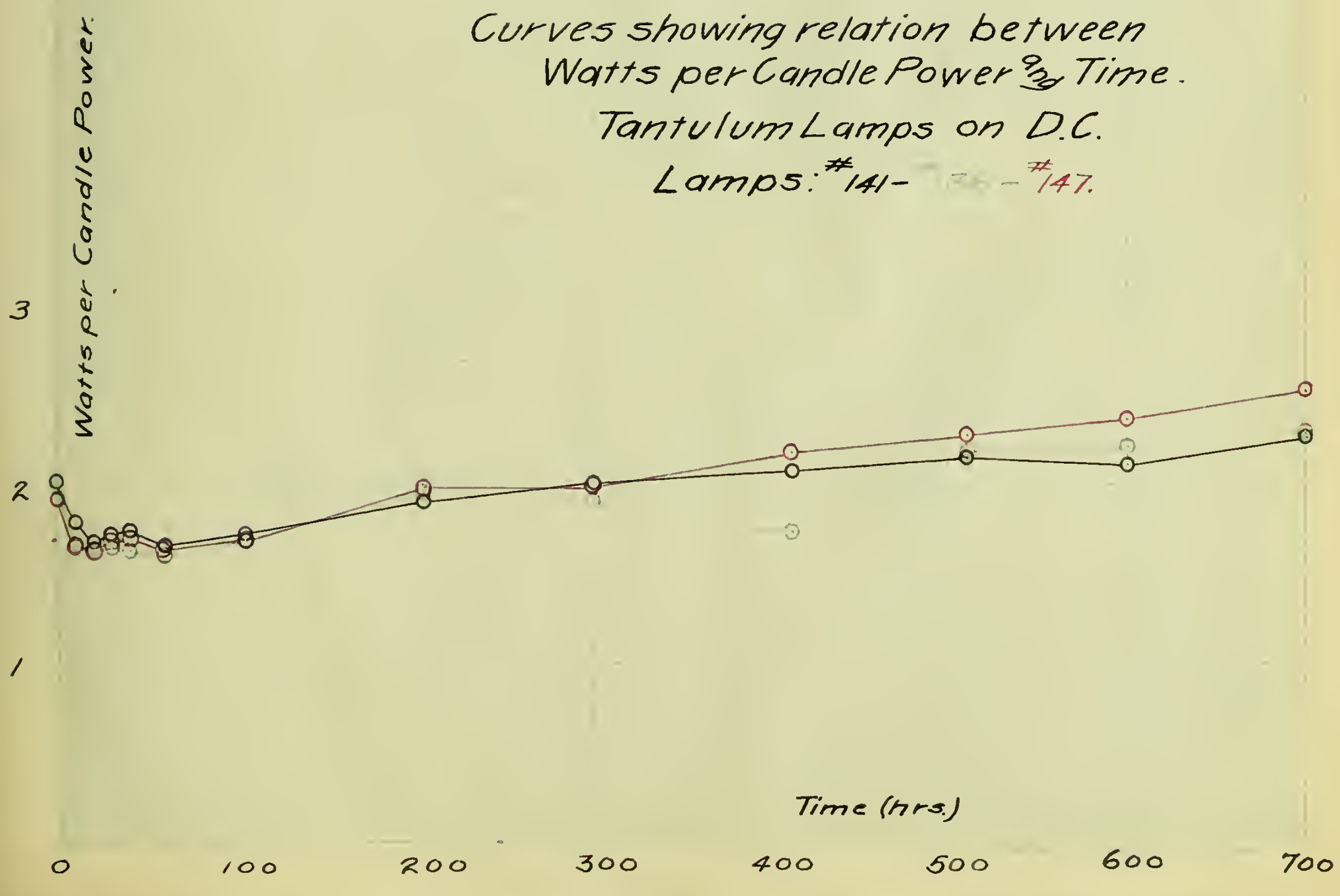
Curves showing relation between
Watts per Candle Power and Time.
G.E.M. Lamps on A.C.
Lamps: #10 – "37 – #45.
Metallized

[illegible]
Ruptured

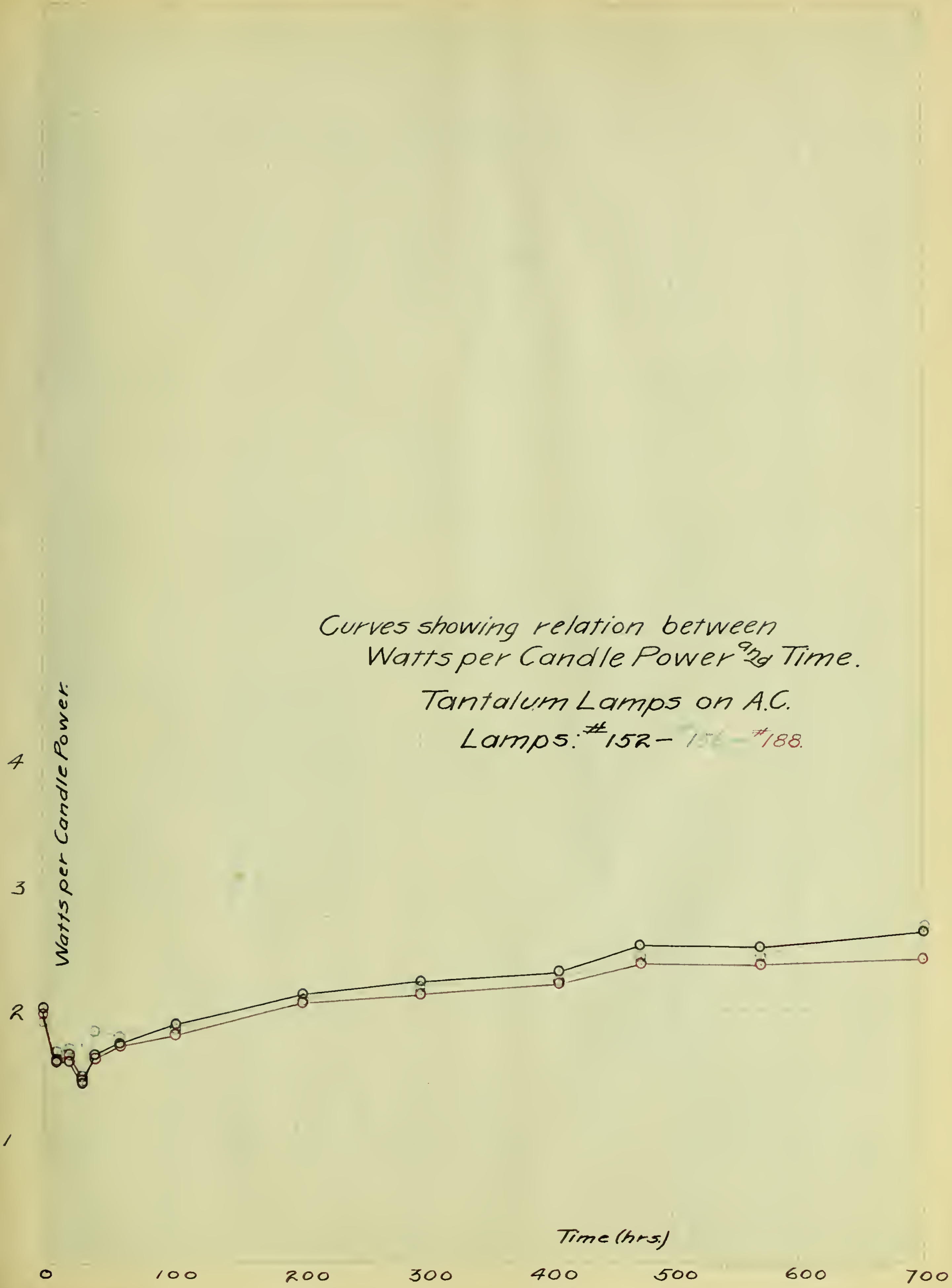


Curves showing performance of Tantalum Lamps on Direct Current


Curves showing performance
of
Tantalum Lamps
on
Alternating Current
Candle Power
Time in hours
Lamp #188
Lamp #156
Lamp #156
Lamp #152
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
0
100
200
300
400
500
600
700



Curves showing relation between Watts per Candle Power and Time.
Tantulum Lamps on D.C.
Lamps: #141 - [illegible] - #147.



Curves showing relation between Watts per Candle Power and Time.

Tantalum Lamps on A.C.

Lamps: #152 – [illegible] – #188.

Carbon on Direct Current					Carbon on Alternating Current				
No. Lamp	Candle Power	Current	Watts C.P.	Hours	No. Lamp	Candle Power	Current	Watts C.P.	Hours
258	25.1	.674	2.95	0	268	25.3	.670	2.91	0
227	25.6	.698	3.00	0	274	24.9	.684	3.02	0
237	25.3	.674	2.93	0	235	25.1	.676	2.96	0
249	24.8	.667	2.96	0	259	24.7	.786	3.50	0
243	24.9	.683	2.97	0	213	25.8	.690	2.94	0
222	25.3	.681	2.96	0	244	25.1	.686	3.00	0
219	24.4	.660	2.98	0	248	25.1	.686	3.00	0
251	24.9	.660	2.92	0	265	25.4	.674	2.92	0
218	24.6	.681	3.00	0	270	25.0	.666	2.93	0
273	24.5	.667	2.99	0	233	25.6	.684	2.94	0
258	25.3	.685	2.95	10	268	24.5	.682	3.06	10
227	25.2	.677	2.86	10	274	25.2	.698	3.04	10
237	26.4	.688	2.92	10	235	25.3	.689	3.04	10
249	25.4	.677	2.95	10	259	23.6	.620	2.89	10
243	25.4	.683	2.97	10	213	26.6	.704	2.90	10
222	25.4	.686	2.95	10	244	24.6	.691	3.09	10
219	25.6	686	2.95	10	248	26.2	.699	2.93	10
251	24.8	.672	2.98	10	265	25.1	.683	2.98	10
218	24.7	.682	3.04	10	270	25.6	.689	2.96	10
273	24.8	.672	2.97	10	230	25.2	.690	3.01	10
258	25.6	.688	2.95	20	268	25.3	.683	2.97	20
227	24.6	.682	3.04	20	274	25.9	.698	2.95	20
237	27.4	.692	2.77	20	235	25.4	.690	3.02	20
249	25.4	680	2.93	20	259	23.0	.620	2.96	20
243	25.6	.683	2.93	20	213	25.8	.702	2.99	20
222	26.4	.686	2.85	20	244	25.4	.687	2.98	20
219	25.5	.688	2.97	20	248	25.8	.700	2.98	20
251	24.8	.672	2.97	20	265	24.8	.683	3.02	20
218	24.6	.684	3.05	20	270	26.0	.687	2.91	20
273	24.4	.674	3.03	20	233	25.2	.691	3.01	20
258	24.8	.688	3.06	30	268	24.4	.681	3.06	30
227	25.0	.680	2.99	30	274	24.8	.695	3.08	30
237	25.5	.690	2.98	30	235	25.1	.688	3.02	30
249	24.6	.680	3.04	30	259	23.7	.619	2.87	30
243	25.3	.684	2.97	30	213	25.0	.700	3.08	30
222	25.0	.684	3.00	30	244	23.8	.684	3.15	30
219	25.1	.686	3.00	30	248	25.6	.698	2.99	30
251	24.3	.673	3.05	30	265	24.3	.682	3.08	30
218	24.8	.682	3.02	30	270	25.0	.689	3.03	30
273	24.3	.674	3.05	30	233	25.1	.692	3.04	30
258	25.6	.688	2.95	40	268	25.0	.680	3.00	40
227	25.0	.680	2.99	40	274	24.3	.695	3.13	40
237	26.2	.693	2.91	40	235	25.4	.688	2.98	40
249	24.8	.678	3.01	40	259	23.9	.620	2.85	40
243	25.2	.687	3.00	40	213	25.9	.698	2.92	40
222	25.6	.685	2.94	40	244	23.8	.684	3.15	40

Carbon on Direct Current.					Carbon on Alternating Current.				
No. Lamp	Candle Power	Current	Watts / C. P.	Hours	No. Lamp.	Candle Power	Current	Watts / C.P.	Hours
219	26.0	.686	2.90	40	248	25.4	.697	3.02	40
251	24.6	.674	3.01	40	265	25.1	.683	2.99	40
218	24.9	.684	3.02	40	270	25.2	.686	2.99	40
273	24.5	.674	3.03	40	233	25.3	.691	3.00	40
258	25.4	.688	2.98	58	268	24.2	.680	3.09	58
227	23.9	.676	3.12	58	274	23.8	.693	3.20	58
237	26.3	.693	2.90	58	235	24.7	.685	3.05	58
249	25.0	.679	2.99	58	259	21.8	.620	3.12	58
243	26.2	.687	2.89	58	213	24.7	.696	3.10	58
222	25.8	.684	2.91	58	244	22.8	.681	3.29	58
219	26.1	.686	2.89	58	248	24.9	.696	3.08	58
251	25.4	.674	2.91	58	265	24.4	.680	3.07	58
218	25.4	.684	2.96	58	270	24.5	.683	3.06	58
273	24.5	.675	3.03	58	233	25.7	.690	2.95	58
258	25.2	.685	2.99	105	268	23.1	.675	3.21	105
227	23.2	.675	3.20	105	274	21.9	.687	3.45	105
237	25.6	.691	2.97	105	235	23.8	.676	3.12	105
249	23.4	.680	3.19	105	259	20.3	.614	3.33	105
243	24.9	.686	3.03	105	213	22.4	.688	3.37	105
222	23.5	.680	3.18	105	244	21.8	.674	3.39	105
219	23.5	.684	3.20	105	248	22.7	.690	3.35	105
251	24.4	.672	3.03	105	265	22.8	.676	3.27	105
218	23.9	.682	3.14	105	270	22.4	.675	3.30	105
273	24.0	.674	3.09	105	233	24.2	.684	3.11	105
258	22.8	.678	3.26	205	268	20.7	.662	3.52	205
227	22.2	.671	3.32	205	274	20.0	.676	3.71	205
237	23.6	.685	3.18	205	235	20.4	.662	3.58	205
249	22.7	.671	3.25	205	259	18.2	.606	3.76	205
243	23.9	.677	3.12	205	213	20.2	.676	3.68	205
222	21.9	.673	3.37	205	244	19.3	.666	3.51	205
219	22.4	.675	3.30	205	248	20.5	.677	3.63	205
251	21.8	.664	3.34	205	265	20.8	.663	3.51	205
218	21.9	.677	3.40	205	270	21.0	.660	3.21	205
273	22.4	.665	3.26	205	233	21.7	.670	3.39	205
258	20.8	.671	3.55	297	268	18.0	.649	3.97	297
227	21.2	.664	3.44	297	274	18.5	.665	3.95	297
237	22.3	.674	3.32	297	235	18.6	.650	3.84	297
249	21.2	.665	3.45	297	259	17.0	.648	4.18	297
243	21.8	.671	3.38	297	213	19.2	.662	3.79	297
222	20.8	.667	3.53	297	244	18.2	.652	3.94	297
219	21.4	.669	3.44	297	248	19.5	.655	3.69	297
251	20.6	.659	3.35	297	265	18.6	.649	3.84	297
218	21.3	.659	3.40	297	270	18.2	.645	3.90	297
273	21.0	.660	3.46	297	233	19.7	.657	3.66	297
258	19.5	.666	3.76	412	268	16.3	.630	4.25	410
227	19.8	.659	3.66	412	274	16.7	657	4.33	410

Carbon on Direct Current.					Carbon on Alternating Current.				
No. Lamp	Candle Power	Current	Watts/C. P.	Hours	No. Lamp	Candle Power	Current	Watts/C. P.	Hours
237	20.4	.670	3.61	412	235	16.4	.636	4.26	410
249	19.4	.660	3.74	412	259	15.5	.588	4.16	410
243	205	663	3.56	412	213	16.4	.648	4.34	410
222	19.5	.656	3.69	412	244	16.4	.641	4.30	410
219	19.3	.662	3.77	412	248	16.7	.651	4.30	410
251	19.4	.650	3.69	412	265	16.4	.638	4.28	410
218	19.8	.662	3.68	412	270	16.1	.626	4.26	410
273	19.5	.651	3.68	412	233	17.0	.640	4.13	410
258	18.0	.660	4.03	510	268	15.4	.621	4.42	474
227	18.3	.651	3.91	510	274	15.9	.651	4.50	474
237	19.4	.661	3.75	510	235	15.8	.631	4.39	474
249	185	.651	3.87	510	259	14.7	.585	4.01	474
243	18.8	658	3.85	510	213	15.6	.642	4.53	474
222	18.0	.650	3.98	510	244	15.5	.638	4.53	474
219	17.5	.652	4.10	510	248	15.8	.648	4.52	474
251	18.2	.641	3.87	510	265	16.4	.631	4.24	474
218	18.8	.652	3.82	510	270	15.5	.620	4.40	474
273	185	.648	3.83	510	233	15.2	.626	4.52	474
258	18.2	.654	3.95	601	268	13.4	.605	4.96	566
227	17.2	.644	4.12	601	274	15.7	.644	4.51	566
237	18.2	.657	3.97	601	235	15.1	.621	4.52	566
249	17.8	.647	4.00	601	259	14.8	.679	5.04	566
243	18.6	.654	3.86	601	213	20.0	.628	3.45	566
222	17.3	.646	4.11	601	244	15.4	.626	4.47	566
219	17.5	.648	4.02	601	248	14.1	.629	4.90	566
251	18.6	.637	3.77	601	265	15.5	.624	4.41	566
218	18.6	.652	3.86	601	270	14.0	.608	4.76	566
273	17.7	.642	3.98	601	233	13.5	.610	4.96	566
258	17.6	.647	4.05	718	268	12.3	.598	5.34	703
227	16.5	.640	4.27	718	274	14.8	.638	4.73	703
237	17.9	.649	3.98	718	235	13.3	.610	5.04	703
249	16.5	.642	4.28	718	259	13.7	.573	4.60	703
243	17.5	.645	4.05	718	213	12.7	.616	5.33	703
222	16.4	.640	4.29	718	244	13.0	.607	5.12	703
219	16.7	.640	4.22	718	248	12.3	.615	5.50	703
251	16.8	.634	4.14	718	265	14.1	.614	4.78	703
218	17.1	.645	4.14	718	273	11.8	.598	5.56	703
273	17.1	.636	4.10	718	233	Burnt out			588

G. E. M. on Direct Current					G. E. M. on Alternating Current.				
No. Lamp	Candle Power	Current	Watts / C. P.	Hours	No. Lamp	Candle Power	Current	Watts / C. P.	Hours
51	20.0	.484	2.67	0	20	20.8	.499	2.64	0
13	20.6	.503	2.69	0	10	20.4	.486	2.62	0
60	21 0	.494	2.59	0	74	20.2	.496	2.70	0
2	20.4	.497	2.68	0	61	21.2	.493	2.56	0
44	21.0	.501	2.63	0	37	20.7	.502	2.67	0
32	21.0	.477	2.50	0	70	20.6	.498	2.61	0
9	20.5	.503	2.70	0	29	20.3	.500	2.71	0
24	20.5	.504	2.69	0	45	20.0	.502	2.76	0
71	20.7	.502	2.67	0	73	20.2	.498	2.71	0
38	20.1	.495	2.71	0	28	20.2	.419	2.28	0
51	19.9	.485	2.68	10	20	20.3	.496	2.69	10
13	20.3	.503	2.73	10	10	19.3	.484	276	10
60	20.1	.496	2.72	10	74	19.4	.497	282	10
2	19.8	497	2.76	10	61	21.4	.494	254	10
44	20.3	.501	2.71	10	37	20.9	.501	2.63	10
32	20.0	.478	2.63	10	70	20.1	.489	2.67	10
9	20.1	.503	2.76	10	29	20.1	.492	2.69	10
24	19.4	.500	2.83	10	45	19.5	.500	2.81	10
71	20.1	.502	2.74	10	73	19.8	.498	2.76	10
38	20.2	.494	2.69	10	28	19.3	.474	2.81	10
51	20.2	.485	2.66	20	20	19.0	.495	2.85	20
13	20.8	.502	2.66	20	10	18.7	.482	2.85	20
60	21.0	.494	2.59	20	74	19.6	.495	2.77	20
2	20.5	.496	2.67	20	61	20.9	490	2.57	20
44	20.6	.502	2.68	20	37	20.3	.500	2.71	20
32	20.1	.478	2.61	20	70	20.1	.488	2.67	20
9	20.3	.503	2.73	20	29	Burnt	out		16
24	19.8	.501	2.78	20	45	19.6	.500	2.80	20
71	19.8	.501	2.77	20	73	19.9	.499	2.75	20
38	19.8	.494	2.74	20	28	19.2	.473	2.70	20
51	19.2	.485	2.77	30	20	19 8	.494	2.75	30
13	19.9	.500	2.75	30	10	18.4	.480	2.84	30
60	19.5	.493	2.78	30	74	18.9	.494	2.88	30
2	19.2	.495	2.83	30	61	20.6	.486	2.59	30
44	19.9	.500	2.76	30	37	20.2	.498	2.71	30
32	19.2	.476	2.73	30	70	19.8	.486	2.70	30
9	20.0	.501	2.75	30	29				
24	19.4	.498	2.83	30	45	19.0	.496	2.87	30
71	19.4	.500	2.84	30	73	19.7	.496	2.77	30
38	19.3	.492	2.81	30	28	19.2	.470	2.69	30
51	19.9	.484	2.67	40	20	20.1	.492	2.69	40
13	20.5	.500	2.68	40	10	19.1	.480	2.71	40
60	20.2	.494	2.75	40	74	19.5	.494	2.84	40
2	19.8	.494	2.81	40	61	21.3	.486	2.51	40
44	20.7	.500	2.66	40	37	20.3	.498	2.69	40
32	20.0	.476	2.61	40	70	20.4	.483	2.60	40

G.E.M. on Direct Current					G.E.M. on Alternating Current.				
No. Lamp	Candle Power	Current	Watts C.P.	Hours	No. Lamp	Candle Power	Current	Watts C.P.	Hours
9	20.8	.500	2.64	40	29				
24	20.0	.500	2.74	40	45	20.0	.497	2.72	40
71	20.9	.498	2.62	40	73	20.0	.496	2.73	40
38	19.7	.492	2.75	40	28	19.1	.474	2.72	40
51	20.1	.482	2.64	58	20	20.1	.492	2.69	58
13	20.7	.500	2.65	58	10	195	.478	2.69	58
60	20.5	.492	2.64	58	74	19.2	.493	2.82	58
2	20.2	.494	2.75	58	61	20.5	.482	2.58	58
44	20.7	.498	2.64	58	37	20.0	.495	2.72	58
32	205	.475	2.54	58	70	20.1	.481	2.63	58
9	63.0[x]	.643	1.12	58	29				
24	20.3	.498	2.70	58	45	19.4	.496	2.81	58
71	20.5	.498	2.67	58	73	19.8	.494	2.80	58
38	204	.491	2.65	58	28	19.1	.468	2.70	58
51	19.5	.479	2.70	105	20	19.7	.488	2.72	105
13	20.1	497	2.72	105	10	18.4	.476	2.84	105
60	20.0	.490	2.69	105	74	194	.490	2.78	105
2	206	.490	2.61	105	61	Burnt	out.		82
44	206	.496	2.64	105	37	20.5	.492	2.64	105
32	19.5	.472	2.66	105	70	19.4	.476	2.69	105
9	20.9	.497	2.62	105	29				
24	20.0	.497	2.73	105	45	194	.492	2.79	105
71	20.6	.494	2.64	105	73	19.6	.491	2.75	105
38	20.0	.488	2.68	105	28	19.1	.465	2.68	105
51	18.8	.475	2.78	205	20	18.1	.481	2.93	205
13	19.2	.493	2.82	205	10	17.5	.468	2.93	205
60	19.2	.485	2.77	205	74	17.6	.483	3.01	205
2	19.5	.485	2.73	205	61				
44	19.5	.492	2.77	205	37	18.1	.484	2.94	205
32	18.6	.467	2.76	205	70	16.6	.466	3.08	205
9	19.6	.493	2.76	205	29				
24	18.8	.492	2.88	205	45	18.1	.487	2.95	205
71	19.7	.492	2.74	205	73	17.5	.484	3.02	205
38	19.1	.482	2.78	205	28	17.4	.458	2.89	205
51	18.2	.471	2.85	297	20	17.4	.478	3.02	297
13	18.9	.489	2.85	297	10	16.8	.464	3.04	297
60	18.7	.482	2.84	297	74	16.7	.478	3.16	297
2	18.9	.480	2.80	297	61				
44	19.2	.489	2.80	297	37	17.6	.476	2.98	297
32	17.4	.461	2.92	297	70	15.2	.457	3.30	297
9	19.1	.490	2.83	297	29				
24	18.9	.489	2.85	297	45	17.4	.480	3.04	297
71	18.6	.488	2.88	297	73	17.3	.478	3.05	297
38	18.8	.480	2.81	297	28	15.8	.451	3.16	297
51	18.0	.459	2.80	412	20	16.6	.471	3.12	410
13	17.6	.484	3.02	412	10	15.4	.459	3.28	410

[x] Filament Crossed

G.E.M. on Direct Current					G.E.M. on Alternating Current				
No. Lamp.	Candle Power	Current	Watts C. P.	Hours.	No. Lamp.	Candle Power	Current	Watts C. P.	Hours.
60	18.2	.479	2.90	412	74	16.2	.470	3.19	410
2	18.0	.478	2.92	412	61				
44	18.4	.483	2.89	412	37	16.4	.469	3.15	410
32	16.9	.459	2.99	412	70	Burnt	out		384
9	18.8	.488	2.86	412	29				
24	18.8	.486	2.85	412	45	16.6	.478	3.18	410
71	18.9	.483	2.81	412	73	16.3	470	3.18	410
38	17.6	.476	2.87	412	28	15.1	.443	3.23	410
51	16.7	.465	3.06	510	20	16.2	.472	3.21	474
13	17.3	.480	3.05	510	10	15.3	.460	3.31	474
60	17.7	.478	2.97	510	74	15.9	.470	3.26	474
2	17.0	.473	3.06	510	61				
44	17.6	.481	3.01	510	37	157	.469	3.28	474
32	16.2	.457	3.10	510	70				
9	18.6	.484	2.86	510	29				
24	17.8	.482	2.98	510	45	16.2	.478	3.25	474
71	17.8	.481	2.98	510	73	15.7	.470	3.30	474
38	17.7	.475	2.95	510	28	13.6	.441	3.57	474
51	17.0	.462	2.99	601	20	15.6	.457	3.22	566
13	16.3	.478	3.23	601	10	14.8	.454	3.37	566
60	17.6	.474	2.97	601	74	14.7	.462	3.46	566
2	16.6	.468	3.10	601	61				
44	17.5	.478	3.01	601	37	Burnt	out		548
32	15.3	.454	3.26	601	70				
9	18.1	.482	2.93	601	29				
24	17.6	.482	3.01	601	45	15.6	.472	3.33	566
71	17.0	.478	3.10	601	73	15.2	.466	3.36	566
38	17.2	.471	3.01	601	28	Burnt	out.		480
51	15.7	.458	3.21	718	20	14.8	.464	344	703
13	16.7	.475	3.13	718	10	14.1	.448	.350	703
60	16.8	.471	3.09	718	74	Burnt	out		638
2	Burnt	out			61				
44	16.3	.474	3.21	718	37				
32	15.0	.451	3.30	718	70				
9	16.8	.480	3.14	718	29				
24	16.8	.480	3.14	718	45	14.9	.468	.344	703
71	16.8	.474	3.11	718	73	14.1	.461	.359	703
38	16.4	.467	3.13	718	28				

Tantalum on Direct Current.

No. Lamp	Candle Power	Current.	Watts / C. P.	Hours.
155	20.4	.365	1.97	0
141	19.7	.364	2.03	0
157	19.5	.362	2.04	0
113	19.4	.362	2.05	0
104	19.1	.365	2.10	0
144	20.0	.373	2.05	0
136	20.5	375	2.01	0
147	20.4	.369	1.94	0
134	20.3	.365	1.98	0
107	19.3	.362	2.06	0
155	25.1	.371	1.62	10
141	23.1	.368	1.75	10
157	23.6	.369	1.72	10
113	24.2	.368	1.67	10
104	24.2	.373	1.69	10
144	23.2	.375	1.78	10
136	24.6	.378	1.69	10
147	24.2	.367	1.67	10
134	23.6	.368	1.72	10
107	24.8	.371	1.64	10
155	26.5	.371	1.54	20
141	23.9	.370	1.70	20
157	24.0	.368	1.68	20
113	23.8	.368	1.70	20
104	24.7	.373	1.66	20
144	24.2	.380	1.72	20
136	24.8	.380	1.68	20
147	24.2	.368	1.67	20
134	24.3	.371	1.68	20
107	24.2	.378	1.72	20
155	24.3	.372	1.68	30
141	23.4	.370	1.74	30
157	Burnt out.			30
113	23.8	.368	1.70	30
104	23.8	.375	1.50	30
144	23.3	.380	1.51	30
136	25.0	.379	1.67	30
147	23.7	.368	1.70	30
134	23.7	374	1.74	30
107	22.9	.370	1.77	30
155	24.2	.372	1.69	40
141	23.1	.370	1.76	40
157				40
113	22.8	.368	1.78	40
104	24.3	.376	1.65	40
144	24.1	.383	1.74	40

Tantalum on Alternating Current

No. Lamp	Candle Power	Current	Watts / C. P.	Hours
152	19.3	.357	2.04	0
156	20.7	.362	1.92	0
125	19.7	.345	1.93	0
153	20.4	.384	2.07	0
130	19.9	.357	1.97	0
149	20.6	.354	1.89	0
135	19.7	.364	2.03	0
188	19.6	.355	1.99	0
103	19.1	.352	2.03	0
124	19.4	.359	2.04	0
152	25.2	3 67	1.60	10
156	24.3	.372	1.68	10
125	22.6	.359	1.75	10
153	23.0	.387	1.85	10
130	24.7	.370	1.65	10
149	23.8	.364	1.68	10
135	24.6	.372	1.67	10
188	25.1	.368	1.61	10
103	23.0	.356	1.70	10
124	24.2	372	1.69	10
152	25.0	.368	1.61	20
156	23.9	.371	1.70	20
125	24.2	.358	1.62	20
153	23.7	.384	1.78	20
130	23.8	.369	1.70	20
149	24.4	.364	1.63	20
135	24.3	.371	1.68	20
188	24.8	.370	1.64	20
103	23.7	.357	1.66	20
124	25.2	.374	1.63	20
152	24.5	.369	1.43	30
156	23.7	.371	1.49	30
125	22.8	.357	1.72	30
153	23.8	384	1.77	30
130	22.8	.367	1.79	30
149	23.6	.362	1.69	30
135	23.4	.370	1.74	30
188	23.2	.368	1.74	30
103	21.8	.357	1.80	30
124	24.7	.374	1.67	30
152	24.4	.368	1.66	40
156	23.4	.372	1.75	40
125	21.7	.355	1.79	40
153	23.3	.385	1.82	40
130	23.4	.370	1.74	40
149	23.3	.363	1.71	40

Tantalum on Direct Current					Tantalum on Alternating Current				
No. Lamp	Candle Power	Current	Watts / C. P.	Hours	No. Lamp	Candle Power	Current	Watts / C. P.	Hours
136	25.4	.381	1.65	40	135	23.2	.371	1.76	40
147	23.5	.370	1.73	40	188	24.8	.368	1.73	40
134	39.5[x]	.425	1.17	40	103	22.3	.357	1.76	40
107	23.5	.369	1.73	40	124	24.5	.374	1.68	40
155	25.6	.372	1.60	58	152	23.0	.366	1.75	58
141	24.3	372	1.68	58	156	23.0	.374	1.78	58
157					125	20.9	.353	1.86	58
113	24.8	.369	1.64	58	153	23.7	.385	1.78	58
104	24.6	.379	1.69	58	130	23.0	.367	1.75	58
144	25.5	.385	1.66	58	149	22.5	.363	1.77	58
136	25.3	.384	1.62	58	135	23.0	.368	1.76	58
147	24.5	.370	1.66	58	188	23.3	.369	1.74	58
134	38.7	428	1.22	58	103	Burnt	out		45
107	24.5	.372	1.67	58	124	23.7	.374	1.74	58
155	24.2	.372	1.69	105	152	20.7	.358	1.90	105
141	23.7	.372	1.73	105	156	21.8	.372	1.88	105
157					125	19.3	.341	1.95	105
113	24.2	.372	1.69	105	153	22.5	.380	1.85	105
104	24.8	.380	1.69	105	130	20.6	.360	1.92	105
144	24.9	.389	1.72	105	149	20.6	.357	1.90	105
136	25.2	.390	1.70	105	135	20.6	.360	1.84	105
147	24.3	.376	1.70	105	188	22.0	.363	1.81	105
134	26.1	.417	1.75	105	103				
107	23.8	.373	1.72	105	124	22.2	.366	1.82	105
155	22.2	.372	1.84	205	152	17.9	.348	2.14	205
141	21.2	.370	1.92	205	156	19.2	364	2.08	205
157					125	15.9	331	2.29	205
113	21.6	372	1.89	205	153	Burnt	out		151
104	21.8	.382	1.92	205	130	18.1	.346	2.10	205
144	22.8	.388	1.87	205	149	18.1	.342	2.08	205
136	21.6	.386	1.96	205	135	17.8	.350	2.16	205
147	20.8	375	1.98	205	188	18.9	.354	2.06	205
134	Burnt	out		160	103				
107	22.5	371	1.81	205	124	19.2	.358	2.05	205
155	20.7	374	1.98	297	152	16.8	.341	2.23	297
141	20.4	.373	2.01	297	156	17.9	.360	2.21	297
157					125	15.5	.326	2.31	297
113	20.1	.375	2.04	297	153				
104	20.6	.382	2.04	297	130	17.9	348	2.14	297
144	20.9	.394	2.07	297	149	16.4	338	2.27	297
136	22.2	.391	1.93	297	135	17.7	.346	2.15	297
147	20.6	.377	2.01	297	188	17.8	.351	2.17	297
134					103				
107	20.8	.373	1.97	297	124	17.7	.352	2.18	297
155	20.2	.373	2.03	412	152	16.1	.339	2.31	410
141	19.7	372	2.08	412	156	17.4	.354	2.24	410

x Broken and Welded

Tantalum on Direct Current					Tantalum on Alternating Current				
No. Lamp	Candle Power	Current	Watts / C. P.	Hours	No. Lamp.	Candle Power	Current	Watts / C. P.	Hours
157					125	15.3	.327	2.34	410
113	19.9	.372	2.05	412	153				
104	19.6	.380	2.13	412	130	16.4	.341	2.29	410
144	20.3	.391	2.12	412	149	16.2	.332	2.25	410
136	21.4	.340	1.74	412	135	16.9	.340	2.21	410
147	18.8	.373	2.18	412	188	17.1	.345	2.23	410
134					103				
107	19.2	.375	2.14	412	124	16.8	.350	2.30	410
155	19.6	.378	2.12	510	152	14.8	.339	2.52	474
141	19.4	.379	2.15	510	156	16.1	.355	2.43	474
157					125	14.0	.320	2.52	474
113	19.2	.378	2.16	510	153				
104	18.7	385	2.27	510	130	16.4	.339	2.27	474
144	19.4	.396	2.25	510	149	15.4	.332	2.37	474
136	19.6	.391	2.19	510	135	16.6	.344	2.28	474
147	18.2	.378	2.28	510	188	16.1	.347	2.37	474
134					103				
107	18.6	.372	2.19	510	124	16.2	.348	2.36	474
155	18.9	.371	2.16	601	152	19.9	.338	1.87	566
141	194	.374	2.12	601	156	16.0	.353	2.43	566
157					125	14.5	.323	245	566
113	17.6	.365	2.12	601	153				
104	18.6	.381	2.25	601	130	Burnt	out		559
144	19.4	.394	2.27	601	149	15.2	.333	2.41	566
136	19.4	.389	2.21	601	135	15.8	344	2.40	566
147	17.4	.374	2.36	601	188	16.1	.345	2.36	566
134					103				
107	18.2	.375	2.26	601	124	16.3	.348	2.35	566
155	17.2	.374	2.39	718	152	14.1	.337	2.63	703
141	18.1	.372	2.26	718	156	14.7	.354	2.65	703
157					125	14.4	.326	249	703
113	16.8	.374	2.45	718	153				
104	17.8	.384	2.37	718	130				
144	17.9	.394	2.42	718	149	14.3	.334	2.57	703
136	187	390	2.29	718	135	Burnt	out		667
147	16.4	.376	2.52	718	188	15.8	.345	2.40	703
134					103				
107	17.7	.376	2.34	718	124	15.1	.348	2.54	703

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